Soil Temperature in the Central Appalachians of West Virginia

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Abstract

Seven sites were instrumented to collect data for soil temperature in Greenbrier and Pocahontas Counties, West Virginia. The wooded sites ranged from 533 m to 914 m in elevation. Data loggers captured temperature of the soil and air for two years at each site. Frequency of data capture was five readings each day. The MAST at each site showed a mesic (>8°C) soil temperature regime during the period of record. Data from a satellite site infers that the frigid soil temperature regime does not begin on north-facing slopes until an elevation of 1100 m is encountered. These results are important for MLRA correlation and coordination of soil survey updates in the Morgantown MO Office.

Background

The development of climatology has given rise to several branches specializing in the various aspects of this science. Consequently, there are presently soil scientists studying the climate of the air layer near the ground as well as the microclimate within the soil itself. Specific phenomena of the air layer near the soil surface, and its practical importance in various fields of human endeavor, have led to the study of the climate within such air layers. Currently, there is now a great deal of research in this field. The soil forms a particular environment wherein climatic phenomena and processes play an important role in mankind's economy. Therefore, in addition to the study of weather, research in the climate of soil itself is of theoretical importance (Shul'gin, 1965). The sites in Pocahontas and Greenbrier Counties, West Virginia are an important addition to current soil temperature research. These sites were installed during early September of 1996 and collected data for two years.

Methods

StowAway temperature loggers store a maximum of 1800 data points during periods ranging from 15 minutes to 360 days. Prior to installation at most of the sites in the Remote Soil Temperature Network (RSTN), StowAway temperature loggers were programmed to collect data every 4 hours and 48 minutes for 360 days. This frequency equals five times each day. Their certified temperature accuracy is ±0.4°C (±0.7°F). (Note: Calibration tests conducted at the NSSC in Lincoln, Nebraska, have indicated an accuracy of ± 0.2°C.)

At each site, a 23-cm (9-in) PVC pipe with a 10-cm (4-in) diameter houses three StowAway temperature loggers and a desiccant pack to absorb excess moisture (Figure 1). Holes drilled in the PVC pipe allows 1.8-m (6-ft) sensor leads to exit outside while the temperature loggers are protected from the weather elements. A high-grade sealant is applied to the caps of the units to prevent water from entering and where the sensor leads exit the PVC pipe.

Figure 1. PVC pipe is used to house three temperature loggers at each site in the study area.

Site installation is initiated by excavating with a sharpshooter or auger to a depth of 50 cm (20 in). Site data are collected and the soils briefly examined to gather a taxonomic classification. One temperature sensor lead is tied to a bush or sapling to capture air temperature and generally placed from 0.9 to 1.2 m (3 to 4 ft) above the soil surface. Two soil temperature sensor leads are installed at each site -- one at the 10-cm (4-in) soil depth and one at the 50-cm soil depth. Finally, the PVC pipe is buried at about 10 cm and covered with soil. After retrieval of the temperature loggers, data were off-loaded in West Virginia. Once off-loaded, the temperature signatures are examined for each of the sites. Temperature data for the West Virginia temperature study were averaged by month, then graphed using Microsoft Excel software (Figure 2).

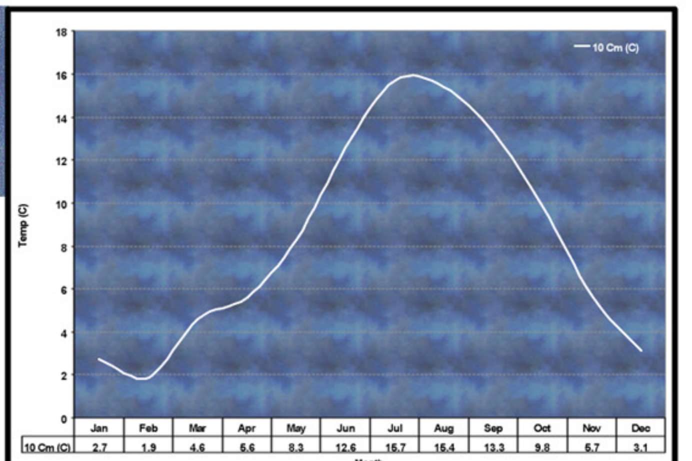

Figure 2. Monthly soil temperature averages Site #7 in Greenbrier County, West Virginia.

Additional analyses are needed to fully understand air and soil temperature. In addition to mean annual air temperature (MAAT) and mean annual soil temperature (MAST), a mean summer temperature (MST) and a mean winter temperature (MWT) are calculated for all sites in the RSTN. The MST is the average for all the readings during June, July, and August while the MWT is the average for all the readings during December, January, and February. An *isotivity value*, or the difference between MST and MWT, is determined at each of the sites in the RSTN to access the extreme seasonal variation.

Study Area

The study area is in the southeast part of West Virginia. Pocahontas and Greenbrier Counties border the state of Virginia, which lies to the east (Figure 3).

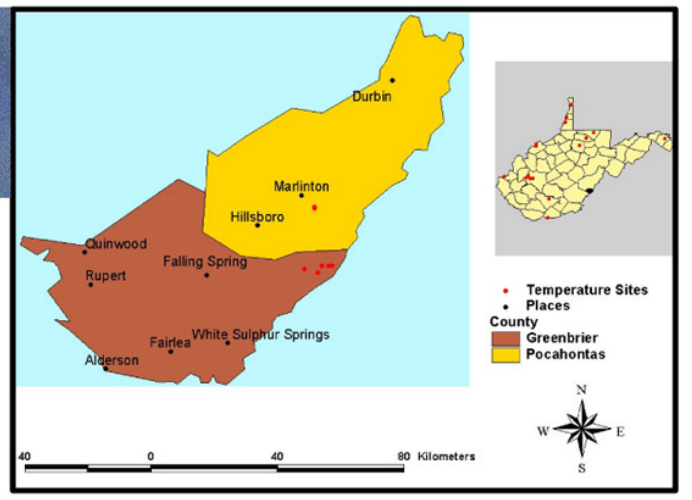

Figure 3. Location of sites in Pocahontas & Greenbrier Counties, West Virginia.

Site and soil information from seven sites and their monthly, seasonal, and annual analyses are shown in Table 1. The forest vegetation at the sites are a mixture of hardwood and softwood species. During this study, Site #1 was paired with Site #2, Site #3 was paired with Site #6, and Site #4 was paired with Site #5. Site #7 occupies a floodplain position in a cold air drain. The period of record for this study was September 10, 1996, to August 29, 1998.

Table 1. Soil and Site Information for the Temperature Study Area in West Virginia

Site (#)	Soil Series (Name)	North Lat. Deg. (°)	West Long. Deg. (°)	Elev. (m)	Slope (%)	Aspect (%)
1	Calvin	38.187370	80.050213	853	25	180
2	Calvin	38.183537	80.050190	853	40	360
3	Berks (Fig. 4)	38.000003	80.040000	853	25	180
4	Berks	38.020000	80.030000	914	25	360
5	Dekalb	38.020000	80.000001	914	28	180
6	Dekalb	38.020000	80.010000	853	45	360
7	Potomac (Fig. 5)	38.010000	80.080001	783	3	350

Figure 4. The Berks soil was identified at two of the sites in the study area.

Figure 5. The Potomac soil at Site #7 is in a cold air drain.

Results

Mean Annual Soil Temperature at 10 and 50 cm for West Virginia were calculated from monthly means using the rules of Soil Taxonomy (Soil Survey Staff, 1999). These summaries are presented in Table 2.

Table 2. Comparison of MAST at 10 and 50 cm for Two Years in West Virginia

Site (#)	MAST Year 1 10 cm (°C)	MAST Year 2 10 cm (°C)	MAST Change 10 cm (°C)	MAST Year 1 50 cm (°C)	MAST Year 2 50 cm (°C)	MAST Change 50 cm (°C)
1	10.2	10.4	+0.2	10.3	10.6	+0.3
2	8.5	9.2	+0.7	8.7	9.0	+0.3
3	9.7	-----	-----	9.7	-----	-----
4	10.2	-----	-----	10.1	-----	-----
5	10.3	-----	-----	10.4	-----	-----
6	8.9	9.7	+0.8	9.1	-----	-----
7	8.2	8.7	+0.5	8.6	-----	-----

Dashed lines indicate that the sensor was inoperative due to vermin damage or battery failure. The tables are arranged by depth and year of data capture. This allows for monthly, seasonal, and annual comparisons between the first year ('96-'97) and the second year ('97-'98).

Annual data show an increase in soil temperature during the second year of the study. It is most expressed at the 10-cm depth. The increase was similar between south and north aspects. These increases are similar to other studies in the Northeast showing a clear trend of increasing soil temperature data since 1996 (Mount, 1999). Moreover, mean annual air temperature data from two sites show that the air temperature increased by 0.6°C (1.1°F) during the second year of the study.

Six of the seven sites were paired to determine differences in MAST based on aspect. Table 3 shows the aspect dependency for soil temperature at 50 cm of all the sites in West Virginia. At every location, the MAST on the south aspect was warmer than on its paired north aspect. The least difference was 0.3°C (0.6°F) at Sites #4 and #5. The largest difference was 1.6°C (2.9°F) at Sites #1 and #2. The trend of MAST versus elevation was low (R^2 <0.1). In fact, there was an increase in MAST with elevation until 975 meters where the MAST then decreased. The mean winter soil temperatures (MWT) were lower on north aspects. The mean summer soil temperatures (MST) were colder on the north aspect at Site #2, but warmer than their counterparts at Site #6 and Site #4. Except for the paired location at Site #1 and #2, the isotivity of the north aspects were greater than those on south aspects.

Table 3. Relationship of Seasonal and Annual Analyses of Soil Temperature to Elevation and Aspect

Analysis	1 South 853 m	2 North 853 m	3 South 853 m	6 North 853 m	5 South 914 m	4 North 914 m
MAST	10.3	8.7	9.7	9.1	10.4	10.1
MST	15.6	13.6	14.7	14.8	15.1	16.1
MWT	4.8	4.2	4.7	3.6	5.7	4.3
MS – MW	10.8	9.4	10.0	11.2	9.4	11.8

Discussion

The soil temperature at seven sites in West Virginia increased, on average, by 0.3°C (0.6°F) during the second year of the study. The soil temperature increased equally on north and south aspects. Being time-dependent, soil temperature shifts either up or down with each 12-month segment of capture.

Figure 6 shows the shift in 12-month segments of Site #7 between August 1997 and August 1998. This figure also shows that the soil starts out mesic (>8.0°C), decreases to frigid during the 3rd shift, and continues to have a frigid soil temperature regime through the 9th shift. It returns to mesic during the 10th shift and increases until the 13th and final shift. These data clearly indicate that a soil temperature regime will shift with Global Climate Warming -- even during a short-term study. So how do we handle dramatic short-term changes for correlation purposes? Probably one of the best ways is to determine a latitude/elevation regression based on measured data.

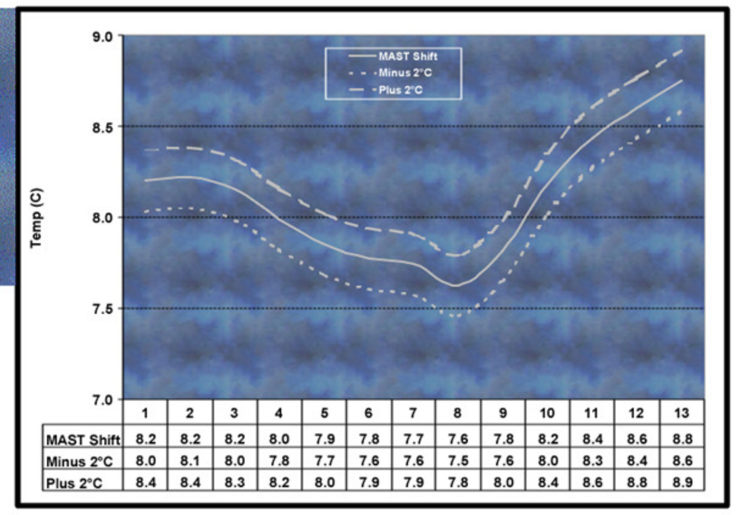

Figure 6. Shift analysis of 4-inch soil temperature at Site #7 in Greenbrier County, West Virginia.

On March 22, 1999, a linear regression equation was generated using TableCurve software (Figure 7). Three points were used as measured data: (1) a site from the Great Smoky Mountains in Tennessee, (2) a site in western Greenbrier County, West Virginia, and (3) a northern site from Cattaraugus County, New York. The elevation component is where the mesic/frigid break has been measured from nearby measured data. With an R^2 of 0.999, this equation can be used to approximate the mesic/frigid soil temperature break on north slopes for any given latitude between North 35° and 43°.

The equation is: Y (latitude in decimal degrees) = a + bx; where a = 46.204504; b = -0.0023030202; and x = elevation (ft).

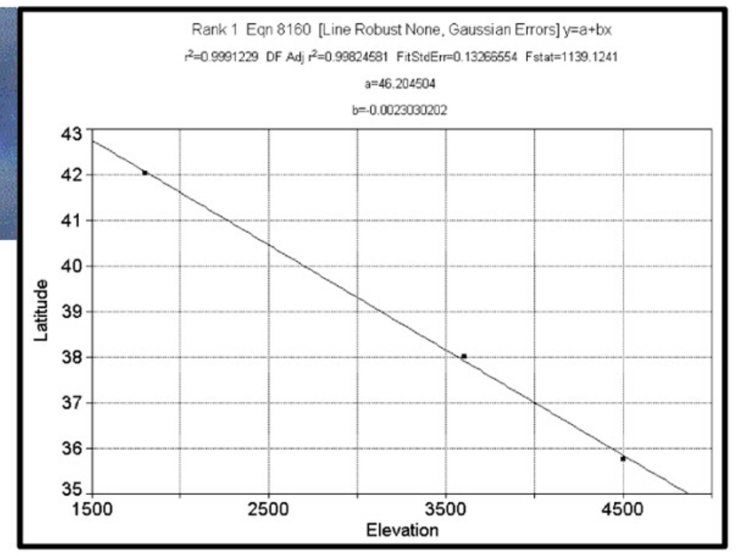

Figure 7. Regression equation to differentiate mesic and frigid soils in MO-13.

This regression equation will continue to be used for correlation purposed in Major Land Resource Area 13. It approximates conceptual temperature divisions as determined by short-term data in Pocahontas and Greenbrier Counties, West Virginia.

Acknowledgments

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